Columbus State University’s Robotic Hand

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ABSTRACT
Columbus State University’s newly founded Robotics Program has been working diligently on a robotic hand that has been designated Da Klaw. Da Klaw will have a controller based on the Nintendo Power Glove, also built and designed by the robotics team. This project design is based on the 3-D printed model from Inmoov with small modifications made by the team and is also in collaboration with Columbus State University’s Coca Cola Space Science Center. In this presentation we will show how our team of students has used 3-D printed parts along with Arduino robotics software and breadboards to assemble and animate the robotic hand. We will also explain future plans for the project and step by step explanation of the process used to create the robotic hand.

Keywords
Da Klaw, Arduino, Inmoov, robotic hand

1. INTRODUCTION
Da Klaw is the product of the first full robotics course under the instruction of Dr. Lavi Zamstein. The hand is placed on a display stand for the purpose of becoming an interactive exhibit located inside the Coca-Cola Space Science Center. It is operated by a wired glove with flex sensors to control the movement of each finger. (See figure 1)

Figure 1. Inner glove showing flex sensors and wiring.

Figure 2. 3D printed parts being sorted for assembly.

2. Da Klaw
Da Klaw is mounted onto a display stand which houses the Arduino Mega 2560 micro controller board along with a small breadboard which serves as a voltage divider. Each flex sensor of the glove is connected to the female end of an Ethernet plug which is mounted onto the wrist portion of the glove. This cable provides both power to each of the sensors and sends the signal that is read by the Arduino to control the hand.

3. ALTERATIONS & ASSEMBLY
3.1 Design Alterations
After downloading and printing the original designs made by Inmoov, the group began to assemble the different parts. As the assembly began they noticed that there were certain parts of the design that needed to be modified in order to completely satisfy the needs for the project. The original design simply had holes in the top portion of the fingers for a fishing line to be fed through and connected to the servo horns. The group quickly realized that this design caused a jittering motion in the fingers from the fishing line slipping through the holes. The decision was made to drill small holes in the palm facing side of the finger tips and insert finishing nails into the holes. The finishing nails were then filed down flush with the plastic and gorilla glued in place. This gave the group somewhere to firmly tie the fishing line down to give the servos a solid pivot point. This alteration allowed the fingers to have more fluid...
movements. The design of the hand only required the servos to be able to rotate 180° and the lightweight plastic used meant a servo with a moderately low torque rating would move the hand through its full range of motion. The Arduino software includes a library for controlling servos that creates shortcuts that allow for shorter and simpler coding. Once the servos were provided a power and grounding source, they were attached to digital pins on the Arduino board. Initial servo control testing was done with simple coding that used potentiometers to control the movement of the servos. After Arduino read the analog input from the potentiometers it mapped the values to 0 to 180 to represent the degrees of rotation of the servos. Once this was done the Arduino wrote the degree value to the servo to set its position. Since the flex sensors also give an analog value this coding was easily applicable to the sensors as well.

Figure 3. Parts organized to show the hands outline.

3.2 Construction

Construction of the hand was a multi-stage process (see figures 2 & 3). The main stages of the build were: brainstorming, planning, and design, gathering the materials, machining, and actual construction. The build consisted of four major parts: the stand, the case, the hand, and the electronics. Once given the assignment the group began to brainstorm about different ways to complete the project. The three dimensional printer was the best way to accomplish the hand itself; while the base and case themselves were best to be built in a woodworking fashion. The electronics, which range from the control glove, to the chip/breadboard, to the actual servos, were another task all alone. Planning was a stage in which the group decided what abilities the hand needed to have. The hand needed to be able to move like a real human hand. It needed to have a wrist that rotated, and all five fingers needed to be able to open and close independently from one another. The group researched many other projects that attempted to accomplish similar goals. This is where the group began to design the hand as it is now. As per the planning constraints the design had to be lightweight, portable, and able to accomplish the tasks asked of it. The hand will be donated to and go on display at the Coca-Cola Space Science Center in Columbus, Georgia. This means that the hand must be accessible to the public and must be able to handle the public interacting with it. The group decided to use a hand design that had been previously made and modify it to fit the constraints for the project. That part of the process out of the way the group turned attention to the stand and case. The stand was designed to be a sturdy table. The case was designed to both show and protect the hand. The materials for the case and electronics were in the classroom, the materials for the stand had to be purchased from Lowes, and the materials for the hand itself were plastics from the three dimensional printer at the Coca-Cola Space Science Center the hand will inevitably be donated to. Once the hand arrived, each piece had to be machined. The holes for the joints to hinge about had to be bored out. An attachment for the fishing cable had to be made into the tip of each finger. The last part of the hand to be changed from the original design was the shielding. A custom logo was inlaid, and the coloration of the hand was changed.

Figure 4. Initial assembly and joint testing.

The hand had to be assembled carefully as the cables were threaded into each individual finger and through the palm (See figure 4). The stand was much more straightforward. Once the materials had been purchased from Lowes, the group fabricated the stand away from class to save time for assembly. The case was made in much the same fashion.
The electronics were assembled in the classroom once all the other components came together. Once all the individual parts came together in the classroom at one time it was time to begin construction. The group set aside several days for construction to allow for troubleshooting and additional machining if needed. The stand was painted while the hand and case came together. The case had to be assembled around the hand. The electronics were the final piece of the project to be added. Once the hand and case were a whole piece, the electronics could be built around the case. The power and signal wires had to exit the case through the rear. Everything besides the power and signal cables is contained inside the case itself. The hand sits above a pedestal which allows the fishing cable to be brought down and separated to the individual servos. The servos are powered via a breadboard while their signal comes from the Arduino chip. Overall the project took place over nearly four months. Various challenges that arose during the design and construction process included modifying original designs, designing structural pieces, coding complex operations, and working with/assembling multiple materials.

3.3 CODING

The means by which the Arduino board received its information from the actual input glove was another concern. The initial idea was to use Bluetooth wireless connectivity to control the robotic hand. This would require an external power source to be attached to the glove; instead Ethernet jacks were used at both the glove and the Arduino board so that any standard Ethernet cable of any reasonable length could be used in order to control the robotic hand. Due to its relative ease of use and wide availability of tutorials and help the Arduino platform was chosen for this program. The design of the hand made using servos ideal for controlling the movement of the wrist and fingers. The project was intended for an interactive exhibit so it was decided that a wearable glove was best for controlling the hand. This made it possible for the hand to be enclosed in a display case while letting visitors to the Center control the hand with minimal contact. Flex sensors were placed along the fingers of the glove to measure the movement of the fingers. The flex sensors that were used to determine the movement of the glove’s fingers increase and decrease resistance across the sensor as it is flexed. They were wired to a voltage divider to produce a varying voltage for the Arduino board to read. This voltage was then read and mapped to 0 to 1023 by the Arduino. The flex sensors are quite sensitive and the Arduino would pick up very slight flex in the sensor producing frequently changing value even when it was not intended. The difference in values from not flexed to fully flexed was around 200 for most of the sensors and when mapped to the range of motion of the servos produced a close to 1:1 ratio. This caused the servos to jitter due to the constantly changing value given by the flex sensors. To counteract this, the analog values were first mapped from 0 to 500 to stretch the values out. The new mapping kept the constant smaller fluctuations from translating to jitter in the servo motors.

3.4 COMMUNICATIONS

Initially it was intended to place an additional Arduino controller board on the glove to handle the reading of the flex sensors, and then send the values to the Arduino in the display stand through Bluetooth communication. The preliminary coding was written to handle this, but the Coca-Cola Space Science Center requested that a wire connection be used rather than Bluetooth to prevent the possibility of interference with other signals being used within the center. With the Bluetooth out of the picture Serial Communication between the glove and stand Arduino boards was looked into. Although this setup would only require two wires running between the two boards it presented a few issues. First this would require a second power source to power the board and sensors on the glove. Also with a modest budget the Arduino Mega on hand was the best option available, but mounting one to the glove would result in unwanted bulk. Third was the programming itself. Using the Easy Transfer Arduino library, the values from the flex sensors were converted to ASCII values and transferred in packets over the TX and RX serial communication ports. This conversion resulted in
unreliable values being given to the servo motors causing reduced response. Additionally, even with a baud rate of 115200 the time lapse between the flex sensors moving and the servos responding was greater than anticipated. With these issues present it was decided to use one Arduino board in the displac stand. A breadboard was placed next to the Arduino to house the voltage dividers for the flex sensors.

3.4.1 STARTUP DEMO
With Da Klaw being planned as an interactive exhibit an initial startup demo was programmed to begin once the Arduino Mega was powered up. This demo was designed to give a brief preview of the movements possible while also being a simple debugger. Since these values are predetermined any lack of movement can be isolated per finger leaving only the possibility of servo or fishing line failure.

3.4.2 Finger Curl
After all the servos are given an initial value of zero, each finger is closed one after the other beginning with the thumb and ending with the pinky. Each finger is then opened in the reverse order, beginning with the pinky and ending with the thumb.

3.4.3 Wave
The wave begins three seconds after the finger curl has ended. All fingers including the thumb are open at the beginning of this phase. The index, middle, ring and pinky fingers are then closed simultaneously. This loop is repeated three times to simulate a simple wave. (See figure 7)

3.4.4 Shaka Sign
One second after the wave is complete the final demo begins. This demo simulates the shaka sign. The thumb and pinky fingers are extended while the three other fingers are closed. The wrist is then rotated back and forth twice. This demo is intended to show whether the wrist servo is operational. A delay of three seconds was placed after this demo, following which control of the hand is transferred to the control glove. (See figure 8)

4. PUTTING IT ALL TOGETHER
Once the hand was assembled and all the cables connected from the tips of the fingers to the servo horns then the program was tested against the actual servos being used instead of the bench top testing servos. The major issue was the flexible resistors giving out a variety of values and no consistency. The feedback values had to be interpolated to match the travel distance of the servo. Once each finger resistor was properly mapped to the appropriate servo motor, the fingers on the hand started obeying the control of the input hand. Mounting the servos on the permanent stand came about by a necessity of space (see Figures 5 & 9). Two servos were mounted in opposition to the other three to try to conserve the space under the robotic hand. The constant moving of the finger cables was going to cause trouble with the cable guides so brass grommets were added to the guides to cut down on and possibly prevent abrasive damage to the guides by the
cables. The servos, Arduino board, coupling breadboard, and all wiring were neatly organized and attached to the stand underneath the robotic hand to allow for viewing of the servos as they operated and to also allow for the troubleshooting and replacement of any of the parts if it were ever required.

![Figure 9. Full assembly of Da Klaw on top of servo housing](image)

5. FUTURE ADDITIONS
In the future Da Klaw will find its home in the Coca-Cola Space Science center. The fishing lines that were installed to translate the movement of the servos to the fingers will be replaced with flex cables to increase performance and reliability plans also include installing a gyroscope on the palm area of the glove. Currently the wrist of Da Klaw only moves during the initial startup demo, but the gyroscope will be used to register the rotation of the users’ wrist to in turn rotate the wrist of Da Klaw. The female Ethernet plug currently mounted to the inner glove will provide the necessary wiring to communicate between the gyroscope and the Arduino, all that will be needed is the instillation of programming.

6. ACKNOWLEDGMENTS
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7. REFERENCES